Evaluation of Proposed Testing and Monitoring Activities at Carbon TerraVault's Monterey Formation 26R Class VI Project

This testing and monitoring evaluation report for the proposed Carbon TerraVault (CTV)-Elk Hills Class VI geologic sequestration (GS) project summarizes EPA's evaluation of the testing and monitoring that the applicant proposes to conduct during and following injection operations into the Monterey 26R Formation. This review identifies preliminary questions for the applicant, includes requests for supplemental information, and provides some considerations for future testing/analytical requirements. Requests for revisions and additional information are presented in *blue, and italic* below.

CTV notes that they will report the results of all injection-phase testing and monitoring activities in compliance with the requirements of 40 CFR 146.91. All post-injection site care monitoring data and monitoring results will be submitted to EPA in annual reports submitted within 90 days following the anniversary date on which injection ceases.

Carbon Dioxide Stream Analysis

To meet the requirements of 40 CFR 146.90(a), CTV plans to analyze the carbon dioxide (CO_2) stream quarterly for the constituents identified in Table 1 of the Testing and Monitoring Plan, which is replicated below.

Parameter	Analytical Method(s)
Oxygen	ASTM D1945
Nitrogen	ASTM D1945
Carbon Monoxide	ASTM D1945
Total hydrocarbons	ASTM D1945
Methane	ASTM D1945
Hydrogen Sulfide	ASTM D1945/D6228
CO_2 purity	ASTM D1945
Total Sulfur	ASTM 3246

There are no EPA-approved analytical methods for CO_2 injection streams, and the methods listed on Table 1 are not included among EPA-approved wastewater analytical methods in 40 CFR Part 136 (nor are they used in other Class VI CO_2 injection permits). Many of the analytes are to be analyzed using ASTM D1945, which is the Standard Test Method for Analysis of Natural Gas by Gas Chromatography. Based on the physical states of natural gas and CO_2, this test may be appropriate for CO_2 injectate analysis; however, no specific information or justification was provided in the application materials and there is no publicly available (free-of-charge) information available about these ASTM methods. Table 4 of the applicant's May 31, 2022 Quality Assurance Surveillance Plan (QASP), Summary of Analytical Parameters for CO_2 Stream, indicates that CTV will use International Society of Beverage Technologist (ISBT) analytical methods for injectate monitoring; these methods differ from the ASTM methods described in the Testing and Monitoring Plan.

Table 4 of the QASP also lists analysis of ethanol using method ISBT 11.0. Although there is no EPA-approved analytical method for ethanol analysis in wastewater, this method is acceptable.

CTV is evaluating several sources of CO_2 as injectate for the project, and states that it will notify EPA prior to switching or adding CO_2 sources so that the sampling procedures can be reassessed. Please note that while multiple CO2 sources can be permitted for injection, EPA requires that every potential source CTV is requesting to be authorized for injection must be clearly identified and characterized for it to be included in the permit as an authorized injection fluid. EPA will also require that a sample of every authorized fluid/source be analyzed prior to initiation of its injection to ensure that its physical/chemical properties are consistent with the pre-permitting characterization.

CTV states it will increase the sampling frequency if there is a significant change in the chemical or physical characteristics of the CO_2 injectate, a change in the CO_2 injectate source, or if the facility or injection well experiences a downtime over more than 30 days. Any change in the injection fluid would require advance notice and written approval from EPA. Addition of a new injection fluid (source) not authorized by the permit would also require a permit modification.

Questions/Requests for the Applicant:

- *EPA requests CTV provide the following information about the carbon dioxide stream for proposed existing sources:*
    - *Identification of specific source(s) and location(s) of the carbon dioxide stream;*
    - *An analysis of the chemical and physical characteristics of the carbon dioxide stream for baseline data, which includes but is not limited to the items below:*
        - *A list of chemicals analyzed, including carbon dioxide and other constituents in the carbon dioxide stream (e.g., sulfur oxides, hydrogen sulfide, nitrogen oxides, water content), with percentages of the constituents in the carbon dioxide stream;*
        - *A description of the sampling methodology;*
        - *Any laboratory analytical parameters and methods used, the name of the laboratory performing the analysis, and official laboratory analytical reports including sample chain-of-custody forms;*
        - *All sample dates and times;*
        - *A tabulation of all available carbon dioxide stream analyses, including any quality assurance/quality control samples;*
        - *Interpretation of the results with respect to regulatory requirements (e.g., the compatibility of the carbon dioxide stream with fluids in the injection zone(s) and minerals in both the injection and the confining zone(s), and with well construction materials);*
        - *Any identified necessary changes to the proposed project Testing and Monitoring Plan due to the chemical and physical characteristics of the carbon dioxide stream to ensure protection of underground sources of drinking water;*
        - *Identification and explanation of data gaps, if any.*
    - *Update of the AoR modeling that incorporates data derived from the analysis of the carbon dioxide stream (e.g., to account for any adverse reactions between the carbon*

dioxide and the well construction materials or subsurface formations or fluids in the model).

- *For proposed future sources EPA requests CTV provide a carbon dioxide study. This study should be conducted using industry-recognized process modeling software to characterize and understand the chemical and physical properties of the carbon dioxide. The modeler should be knowledgeable about the industrial processes of the facility where the carbon dioxide stream will be sourced from.*
- *Please provide additional information on the ASTM methods listed in Table 1, including why CTV considers them to be appropriate for CO_2 injectate analyses. For example, ASTM D1945 is for the analysis of natural gas. Does the method clearly indicate that it can be used to analyze CO_2 injectate?*
- *Please update Table 1 to reflect that the analytical method for total sulfur is ASTM D3246 (the "D" is missing from the table).*
- *Please reconcile the discrepancy in the analytical methods in Table 1 of Attachment C vs. Table 4 of the QASP.*
- *Please add analysis of ethanol using ISBT method 11.0 to Table 1 to be consistent with Table 4 of the QASP.*
- *Please add quarterly sampling of argon, hydrogen, oxides of nitrogen, ammonia, and δ13C to the list of analytes to fully characterize the CO_2 stream.*
- *Please also add H_2O as a CO_2 stream analyte on Table 1 to provide information about the presence of free phase water.*
- *ASTM D3246 appears to have several available subparts for various substances to be tested; please specify the method to be used for sulfur analysis of the CO_2 injectate.*
- *Please clarify the year of all the ASTM methods (e.g., ASTM D3246-15) in Table 1.*
- *CTV states that quarterly sampling will begin three months after the date of authorization of injection; please revise this timeline to begin three months after the commencement of injection so that the testing schedule is consistent with injection operations.*

Considerations based on the results of Pre-Operational Testing/Modeling Updates:

- *EPA will require that a baseline injectate sample be analyzed for the same parameters as in the Testing and Monitoring Plan prior to commencement of injection.*
- *If the baseline injectate sample or any updated information about injection formation fluids indicates that any injectate constituents may lead to geochemical reactions that could affect operations or change aquifer properties, additional analytical parameters for the injectate analysis may be required.*

Injection Well Testing

The subsections below describe: the planned quarterly corrosion monitoring; continuous recording of injection pressure, rate, and volume to evaluate internal mechanical integrity; and annual external MITs that will meet the requirements at 40 CFR 146.90(b), (c), and (e). CTV plans to inject CO_2 via four injection wells, including one existing well (373-35R) and three wells to be constructed (Well 345C-36R, Well 363C-27R, and Well 353XC-35R). CTV is required to submit a Testing and Monitoring Plan for each

well, with unique well-specific testing (particularly for corrosion monitoring and continuous monitoring) that reflects each well's design.

Corrosion Monitoring

CTV proposes to conduct corrosion monitoring using the coupon method. The corrosion coupons will be placed in the pipeline that feeds CO_2 injectate to the injectors. Corrosion monitoring will occur between the compressor and wellhead, according to Table 1 of the QASP.

Samples of the materials used in the construction of the pipeline and injection well that are exposed to CO_2 injectate will be monitored for corrosion using corrosion coupons. Representative materials will be weighed, measured, and photographed prior to installation. The coupons will be sent to a lab and photographed, measured, visually inspected, and weighed to a resolution of 0.1 milligram. The specific methods by which the samples will be handled are not described in the Testing and Monitoring Plan; however, Table 5 of the QASP indicates that analytical methods include NACE TM0169/G31 and EPA 1110A SW846.

CTV says that, if the corrosion rate is greater than 0.3 mils/year, it will initiate consultation with regulatory agencies (but does not specify which agencies), and may run a casing inspection log to assess the thickness and quality of the casing.

The proposed coupons will be composed of the materials summarized in Attachment C, Table 3. The first two columns of the table below are adapted from Table 3 of the Testing and Monitoring Plan (list of equipment coupon with material of construction), and the columns to the right document the materials described in the Well Construction, Operation, and Plugging (COP) Details dated May 31, 2022 for each injection well.

Coupon (Attachment C, Table 3)	**Coupon Material (Attachment C, Table 3)**	**COP Details: Well 373-35R**	**COP Details: Well 353XC-35R**	**COP Details: Well 363C-27R**	**COP Details: Well 345C-36R**
Pipeline	CS A106B	None provided	None provided	None provided	None provided
Casing	N80 and K55 steel	K55, N80, and H40 steel (Table 1)	L-80 CRA (Table 1)	L-80 CRA (Table 1)	L-80 CRA (Table 1)
Tubing	13 CR L-80	L-80 CRA (Table 2)	L-80 CRA (Table 2)	L-80 CRA (Table 2)	L-80 CRA (Table 2)
Wellhead	Stainless steel	Stainless steel or other material consistent with accepted industry practices (pg. 3)	Stainless steel or other material consistent with accepted industry practices (pg. 3)	Stainless steel or other material consistent with accepted industry practices (pg. 3)	Stainless steel or other material consistent with accepted industry practices (pg. 3)

For Well 373-35R, the coupons proposed for corrosion monitoring match those for the wellhead, tubing and the intermediate and long string casing, but not the surface casing, as described in the COP details. For wells 353XC-35R, 363C-27R, 345C-36R, the coupons proposed for corrosion monitoring match those for the wellhead and tubing, but differ from those described for all casing strings. Although the materials of construction for the pipelines are not described, it is assumed that coupons would be selected to represent these materials.

Questions/Requests for the Applicant:

- *Please clarify the discrepancies between the casing construction and the coupons planned for each of the injection wells noted above.*
- *Please clarify that CTV will discuss any detected corrosion rate of more than 0.3 mils/year with EPA.*
- *For completeness, please include the details about the analytical methods for corrosion coupon monitoring that are described in Table 5 of the QASP into the Testing and Monitoring Plan.*
- *Under "monitoring details," Attachment C says that the coupons will be sent to a lab for analysis every 6 months. Corrosion monitoring must be performed on a quarterly basis, per 146.90(c); please revise the Testing and Monitoring Plan accordingly.*
- *Please provide a Testing and Monitoring Plan for each well, with unique well-specific testing (particularly for corrosion monitoring and continuous monitoring) that reflects each well's design.*

Continuous Monitoring to Evaluate Internal Mechanical Integrity

CTV will install and use continuous recording devices to monitor: injection pressure, rate, and volume; the pressure on the annulus between the tubing and the long string casing; the annulus fluid volume added; and the temperature of the CO_2 stream, as required by 40 CFR 146.88(e)(1), 146.89(b), and 146.90(b).

A surface pressure gauge will be installed on the annulus to monitor the annular pressure and ensure the integrity of the packer and tubing. However, the annular pressure needed to signify a mechanical integrity issue is not indicated by CTV. The plan states that pressure and temperature gauges will be calibrated as shown in Table 6 of the QASP. According to that table, the pressure gauges allow measurement up to 5,000 psi, which exceeds the surface and downhole pressures anticipated in all four injection wells.

The injection rate will be monitored by a surface flowmeter. Injection volume and mass will be calculated using the injection flow rate and CO_2 stream density and will be used to ensure the maximum expected injection volume does not exceed 38 million tonnes.

Temperature gauges will be employed at the surface and downhole to monitor the temperature of the injectate and ensure it is consistent with the expected temperature of the CO_2 stream at a given depth.

Table 2 of Attachment C lists sampling devices, locations, and frequencies for continuous monitoring and is replicated below.

Parameter	Device(s)	Location	Min. Sampling Frequency	Min. Recording Frequency
Injection pressure	Pressure Gauge	Surface and Downhole	30 seconds	30 seconds
Injection rate	Flowmeter	Surface	30 seconds	30 seconds
Injection volume	Calculated	Surface	30 seconds	30 seconds
Annular pressure	Pressure Gauge	Surface	30 seconds	30 seconds
CO_2 stream temperature	Temperature gauge	Surface and Downhole	30 seconds	30 seconds

Questions/Requests for the Applicant:

- *Please include the location/depths of the downhole temperature and pressure gauges listed on Table 2.*
- *Please add monitoring of the annulus fluid volume to Table 2 to match the activities required at 40 CFR 146.90(b).*
- *Please explain the appropriateness of a 30 second minimum sampling and recording frequency versus at a higher frequency (e.g., 10 seconds).*
- *Please include a surface temperature gauge on the injection well schematics to reflect CO_2 stream temperature monitoring in Table 2.*
- *Please explicitly define the annular pressure deviation that would warrant a mechanical integrity investigation (as described on pg. 5).*

External MITs

To verify external mechanical integrity as required at 40 CFR 146.89(c) and 146.90, CTV proposes to perform MITs annually. CTV also proposes to perform these same MITs prior to commencing injection.

Table 6 of Attachment C lists the MITs to be performed and is reproduced below.

Test Description	Location
Temperature Log	Along wellbore via wireline well log
Radioactive Tracer Survey (RTS)	Along wellbore via iodine

On page 9 of Attachment C, CTV only indicates that it will run a temperature log (and not a radioactive tracer log) and notes that, if it elects to conduct an alternate MIT, it will request approval from EPA. (EPA notes that, if CTV opts to use an alternative MIT, the Class VI permit would need to be modified to incorporate this test.) CTV presents procedures for MIT temperature logging but does not describe the radioactive tracer logging procedures. The Emergency and Remedial Response Plan includes scenarios for monitoring well MI failures, however no MIT of the monitoring wells is described in the Testing and Monitoring Plan.

Questions/Requests for the Applicant:

- *Please revise the temperature logging procedure to include a minimum of 4 hours between runs. Additionally, please provide more extensive temperature logging procedures, e.g., in accordance with the document, "Appendix E – Temperature Logging Procedures – U.S.E.P.A. Region IX," which is available online at: https://archive.epa.gov/region9/water/archive/web/pdf/appendixetemplogreqs.pdf.*
- *Please provide a detailed description of the testing procedures for the planned RTS.*
- *Table 6 describes the location of the RTS to be "along wellbore via iodine" it is assumed that this refers to the specific tracer to be used. Please clarify and edit the table to read "along wellbore via iodine tracer," if appropriate.*
- *CTV states that MITs will be performed annually, within 30 days of the injection authorization date. Please revise this timeline to coincide with the commencement of injection so that the testing schedule is consistent with injection operations.*

- *Please include procedures and plans for performing internal and external MITs for the Monterey Formation monitoring wells (341-27R, 328-25R, and 376-36R) and the Etchegoin Formation monitoring well (355X-26R) during the injection and post-injection phases and describe these in Attachments C and E.*

Pressure Fall-Off Testing (PFOT)

CTV states that it "does not currently plan to complete pressure fall off testing" (pg. 10), given the extent of available information about the Monterey 26R Formation. CTV says that it will consider pressure fall-off testing if the injection rate decreases, with a simultaneous injection pressure increase outside the results of computational modeling. A pressure fall-off test must be performed prior to injection and at least once every 5 years, per the Class VI Rule at 40 CFR 146.90(f).

Attachment C also provides a brief description of PFOT procedures.

Questions/Requests for the Applicant:

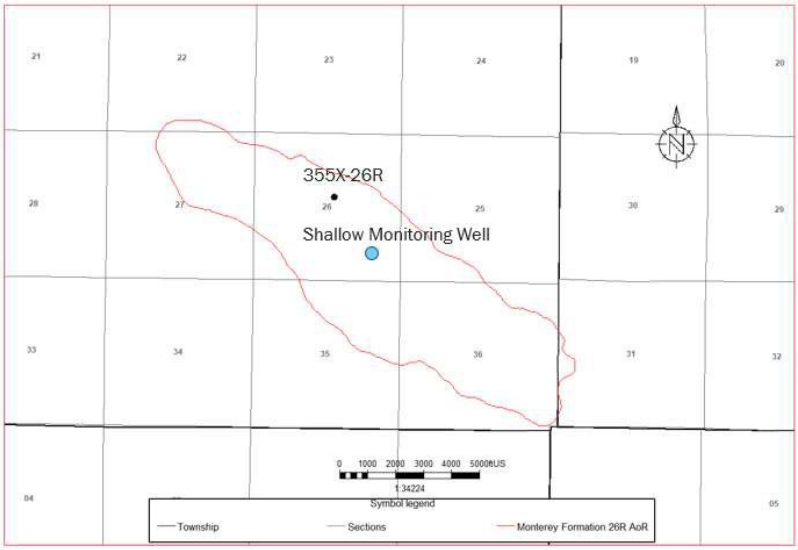
- *Please clarify in the Testing and Monitoring Plan that a pressure fall-off test will be performed prior to injection and every 5 years during the injection phase, as required by 40 CFR 146.90(f).*
- *Please provide more detailed PFOT procedures, e.g., in accordance with the document, "EPA Region 9 UIC Pressure Falloff Requirements," which is available online at: https://archive.epa.gov/region9/water/archive/web/pdf/falloff-testing-guidlines.pdf.*

Groundwater Quality Monitoring

CTV proposes to monitor groundwater quality above the confining zone using direct and indirect methods. To meet the requirements of 40 CFR 146.90(d), CTV proposes to perform the following monitoring above the confining zone:

- Annual injection-phase water quality monitoring and continuous pressure and temperature monitoring via one shallow monitoring well located within the delineated AoR in the Upper Tulare Formation. This well has not yet been drilled, but will be at a depth of 0 to 1,100 feet. Post-injection water quality sampling will continue annually and continuous pressure and temperature monitoring is proposed in the Upper Tulare Formation.
- Continuous injection- and post-injection phase monitoring of pressure and temperature in the Etchegoin Formation in well 355X-26R located within the central portion of the AoR. Table 1 of Attachment E also describes annual post-injection fluid sampling in the Etchegoin Formation in well 355X-26R.

Figure 1, which shows the locations of the above-confining zone monitoring wells, is reproduced below.



Both of the above confining zone monitoring wells are situated within the AoR and in the anticipated path of the CO_2 plume and pressure front (based on information in Attachment B). CTV states (pg. 7) that additional Upper Tulare monitoring wells will be drilled if increased pressure is observed in the Etchegoin Formation monitoring well or water quality changes in the Tulare Formation that is due to Monterey Formation 26R CO_2 injection. However, it is unclear how a linkage of water quality/pressure changes to CO_2 injection (and not other activities) would be made.

The analytical methods and field parameters for water quality monitoring in the Upper Tulare Formation and the Monterey Formation are described in Tables 5 and 8 of Attachment C (injection-phase monitoring of the Tulare and Monterey Formations, respectively), and are nearly the same as those in Tables 2 and 5 of Attachment E. Additional information about monitoring in the Monterey Formation is described under "CO_2 Plume Tracking" below. CTV also proposes to perform a baseline water quality analysis in the Tulare Formation monitoring well. In the May 15, 2022 version of the permit application

narrative (pg. 8), CTV states that the Etchegoin Formation will dissipate CO_2, and CTV will drill and equip a monitoring well to assess formation pressure and water quality changes during the project; however, no injection-phase water quality monitoring in the Etchegoin is described in the Testing and Monitoring Plan.

Table 5 of Attachment C (Injection-phase Tulare Formation monitoring) is reproduced in the first two columns of the table on the next page. Because consistency of monitoring parameters above and within the injection zone is appropriate for detecting water quality changes due to leakage of the CO_2 plume, EPA evaluated proposed injection and post injection monitoring in the Tulare and Monterey Formations together. EPA's notes and recommendations are provided in the right-hand column; see also the discussion of "Quality Assurance Procedures" below for additional comments on the parameters to be monitored.

The parameters appear to be generally appropriate for groundwater quality monitoring needs for GS projects, and are consistent with other Class VI monitoring programs, except as noted below. As the permit application narrative describes (pg. 33), the Monterey 26R Sands are dominated by quartz and feldspar, which are stable in the presence of CO_2 and carbonic acid. Note that, as additional information is gathered based on the reviews of other parts of the permit application or pre-operational data collection, recommendations or requirements for additional analytical parameters may be provided.

CTV should note that the Central Valley Water Board indicated in its consultations with EPA on a prior Class VI project that any newly drilled monitoring wells must be approved by the Water Board and, while existing wells would not need to be approved, the Water Board expressed interest in any plans to use existing wells as monitoring wells.

Attachment C also describes the water quality sampling procedures, the laboratory to be used, and chain of custody procedures. This information is detailed in the QASP as well.

Parameters	Analytical Methods	Evaluation Notes/Recommendations
Tulare Formation		
Cations (Al, Ba, Mn, As, Cd, Cr, Cu, Pb, Se, Tl)	ICP-OEC EPA 200.7/6010B	*200.7 and 6010B are both ICP-AES methods, not ICP-OEC. Please explain what ICP-OEC is or revise the table.* *In Tables 3 and 17 of the QASP, the final cation is Ti, not Tl as in Attachment C. Please clarify/be consistent. Also, this is "T1" in the tables of Attachment E; please correct the typographical error.* *Cations of Zn are also mentioned in Table 3 of the QASP and cations of Sb are also mentioned in Tables 3 and 17 of the QASP; please add these to the ground water monitoring parameters in Attachments C and E.* *200.7 is an EPA-approved wastewater analytical method, while 6010B is not. EPA requests that Method 200.7, Rev 4.4 (1994) be specified.*
Cations (Ca, Fe, K, Mg, Na, Si)	ICP-OEC EPA 200.7/6010B	*See above.*
Anions (Br, Ca, F, NO3, SO4)	Ion Chromatography, EPA Method 300.0	*Attachment E and Tables 3 and 17 of the QASP also include anions of Cl; please add this to Attachment C for consistency and completeness.* *Tables 2 and 5 of Attachment E reference EPA Method 300; please revise the method to be consistent with Attachment C (i.e., Method 300.0). Also, please specify that EPA Method 300.0, Rev. 2.1, Part A (1993) will be used.*
Dissolved CO_2	SM 4500-CO2-C	No comments.
Total Dissolved Solids	SM 2540 C	*Attachment E refers to SM 4500 C for TDS; EPA requests the use of SM 2540 C for consistency.*
Alkalinity	SM 2320 B	*Attachment E refers to SM 2510, which is for conductivity, not alkalinity. EPA requests that CTV revise Attachment E to reference SM 2320 B for consistency. (SM 2320 B is an approved wastewater method.)*
pH (field)	EPA 150.1 / SM4500-H+B	No comments.
Specific Conductance (field)	SM 2510 B	*SM 2510 B is named by SM as a laboratory method, and it is not clear whether SM 2510 B can be conducted in the field. EPA Method 120.1 may be more amenable to field screening if SM 2510 B is not. Please clarify if field use of SM 2510 B is possible or revise the table (i.e., field vs. lab designation) or the method.*
Temperature (field)	Thermocouple	No comments.
Dissolved Methane	RSK-175/Gas Chromatography	*This method was developed by EPA but is not an EPA approved method for wastewater analysis. Please update to reflect using EPA-approved method SM 6211 B and/or 6211 C.*

Questions/Requests for the Applicant:

- *Please update Tables 5 and 8 of Attachment C and Tables 2 and 5 of Attachment E as requested in the table above. Further, the same analytes and methods should be used for monitoring in all formations to provide consistent data to support modeling reviews and a non-endangerment demonstration.*
- *Please include additional ground water quality parameters to support a robust monitoring program, as follows:*
    - *δ13C and H_2S, which are mentioned in the QASP, but not in Attachments C and E.*
    - *Water density (which is referenced in the Testing and Monitoring Plan as an expected water quality change due to plume movement on pg. 11).*
    - *Dissolved O_2, which is a primary indicator of water quality.*
- *Please include sampling/measurement depths in Table 4 of Attachment C and Table 1 of Attachment E for clarity and completeness.*
- *Please revise the Testing and Monitoring Plan to specify that gauge and DTS monitors will be used in well 355X-26R to monitor pressure and temperature in the Etchegoin Formation, as shown on Table 2 of the QASP.*
- *Please include quarterly (rather than annual) water quality monitoring during the injection phase to: confirm that the CO_2 is being confined, help validate modeled predictions, and eventually support the non-endangerment demonstration.*
- *Please add water quality monitoring of the Etchegoin Formation in Table 5 of Attachment C to be consistent with the post-injection monitoring in the revised Attachment E and to provide earlier warning of water quality changes than would be identified in the Tulare Formation monitoring well. Baseline sampling and sampling on a similar schedule to Tulare monitoring is requested.*
- *Please revise Table 2 of Attachment E to indicate that the same parameters will be monitored in the Etchegoin Formation as in the Tulare Formation.*
- *Please explain the appropriateness of a single Tulare Formation monitoring well location relative to the anticipated direction of plume and pressure front movement, and, given the size of the injection operation.*
- *The PISC and Site Closure Plan states (on page 4) that sampling in the Tulare Formation will occur every 5 years, and Table 1 lists the Tulare Formation fluid sampling frequency as annual. Please revise the text to match Table 1.*
- [redacted] Ex 4
- *The Testing and Monitoring Plan states, on page 7, that additional shallow monitoring wells would be drilled if pressure or composition changes due to CO_2 injection are detected. Please describe how this linkage to CO_2 injection would be made.*

Considerations based on the results of Pre-Operational Testing/Modeling Updates:

- *If new information or updates to the geochemical modeling based on pre-operational testing raises additional concerns about subsurface geochemical processes (e.g., potential changes in subsurface properties or potential contaminant mobilization), the list of groundwater quality*

analytical parameters may need to be updated to ensure that all applicable parameters are included.

CO_2 Plume and Pressure Front Tracking

The applicant describes planned CO_2 plume and pressure front tracking that includes the use of direct and indirect methods for tracking the extent of the CO_2 plume and pressure front during the injection phase [40 CFR 146.90(g)(1),(2)].

CTV will employ direct and indirect methods during the injection and post-injection phases to track the extent of the CO_2 plume and the presence or absence of elevated pressure to ensure confinement of the reservoir and consistency with computational modeling results.

CO_2 Plume Monitoring

CTV proposes to monitor the plume via direct and indirect monitoring in the Monterey Formation:

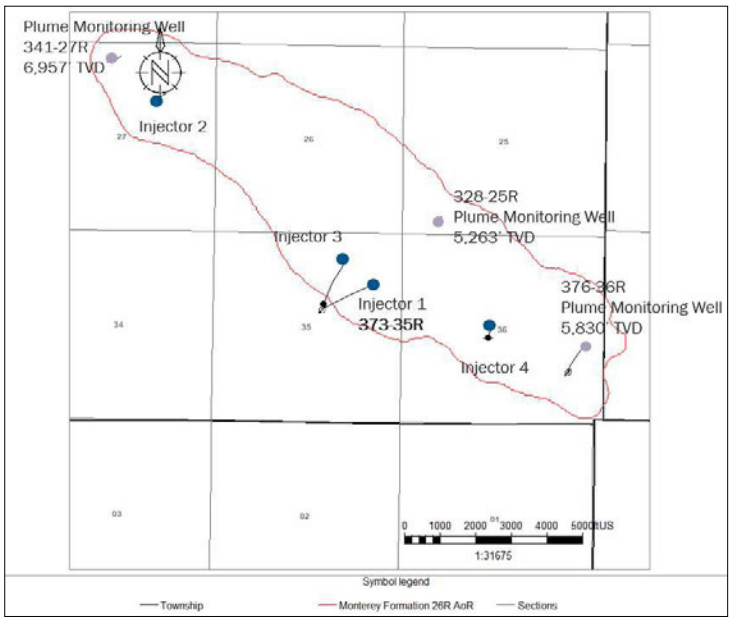
Direct plume tracking methods include: annual fluid sampling during the injection and post-injection phases in Monterey Formation 26R Sands via three monitoring wells (341-27R, 328-25R and 376-36R, located in the northwestern, central, and southeastern portions of the AoR).

Indirect plume monitoring includes: pulse neutron logging in the Monterey Formation 26R Sands via the same monitoring wells. This logging will be conducted every two years during the injection phase and every 5 years during the post-injection phase.

The methods that will be used to monitor the CO_2 plume in the injection and post-injection phases are summarized in Table 7 of Attachment C and Table 4 of Attachment E, respectively. The parameters and associated analytical methods are presented in Table 8 of Attachment C and Table 5 of Attachment E. They are identical to those proposed for Tulare Formation water quality monitoring described under "Ground Water Monitoring" above. EPA recommends that deep and shallow water quality monitoring involve the same parameters to provide consistent data on which to evaluate potential fluid movement out of the confining zone.

Figure 2 of Attachment C (reproduced below) shows the location of the monitoring wells in the Monterey Formation 26R Sands. Schematics for the three deep monitoring wells are provided in a confidential file dated May 15, 2022.

Pressure Front Monitoring



CTV plans to conduct **direct pressure front monitoring** by continuously monitoring pressure and temperature during the injection and post-injection phases within the Monterey Formation 26R Sands via pressure gauges in monitoring wells 341-27R, 328-25R, and 376-36R.

Indirect pressure front monitoring will be accomplished via seismic monitoring throughout the AoR. CTV states that it will monitor seismicity with surface and shallow borehole seismometers it plans to install, as well as monitor seismic data from the Southern California Earthquake Data Center (SCEDC) network. This continuous monitoring will continue throughout the injection and post-injection phases.

Pressure-front monitoring activities are summarized in Table 9 of Attachment C and Table 6 of Attachment E.

Questions/Requests for the Applicant:

- *Please refer to EPA's questions and recommendations under "Groundwater Monitoring" above regarding water quality analysis and revise Table 8 of Attachment C and Table 5 of Attachment E accordingly.*
- *At what point (i.e., in which year of the injection or post-injection phase) does CTV anticipate that the CO_2 plume will reach each of the Monterey Formation monitoring wells?*
- *Please edit Table 8 of Attachment C to refer to the Monterey Formation, rather than the Tulare Formation.*
- *Please describe the seismic monitoring network discussed on pg. 15 of Attachment C, including the number and location of the seismometers that CTV proposes to install.*

- *Please explain the timeframe for which a seismicity baseline will be established. Please explain how historical seismicity will be incorporated into this baseline.*
- *Page 11 of Attachment C says that CTV plans to perform direct pressure monitoring in the Monterey 26R Formation (similar information is presented on Table 2 of the QASP), and Table 9 indicates that pressure and temperature monitoring will be performed. Please revise the statement on pg. 11 to be consistent with the table, i.e., to include temperature as well as pressure monitoring.*
- *EPA recommends that the sampling/measurement depths be included in Tables 7 and 9 of Attachment C and Tables 4 and 6 of Attachment E for clarity and context.*
- *Attachment C states (on pg. 11) that, if the plume development is not consistent with modeling results, CTV will assess whether additional monitoring of the plume is necessary. Please clarify that this determination would be made in consultation with the UIC Program Director and that this would trigger an AoR reevaluation, per the AoR and Corrective Action Plan.*
- *Please explain how the downhole tubing pressure gauges (shown on the schematic for well 341-27R) and downhole injection pressure gauges (wells 328-25R and 376-36R) will monitor pressure within the reservoir for pressure front tracking.*

[redacted] Ex 4 [redacted]

- *Please update Figure 2 of Attachment C to include the injection well numbers for Well 353XC-35R, 363C-27R, and Well 345C-36R.*
- *Please make the following changes to the proposed plume and pressure front tracking in Attachments C and E:*
    - *Perform frequent sampling and logging (e.g., quarterly) early in the injection phase (i.e., at least until the CO_2 plume passes the monitoring well locations). This would allow the acquisition of additional data to validate the modeling, provide early warning of unanticipated fluid movement, and be consistent with other Class VI projects.*
    - *Conduct a 3D seismic survey or a vertical seismic profile during injection operations for comparison to the 2019 3D seismic survey described in the application narrative.*
    - *Conduct quarterly water quality sampling in the Monterey Formation for plume tracking as well as to provide additional data points to validate modeled predictions and to eventually support the demonstration of non-endangerment.*

Air/Soil or Other Testing and Monitoring

Based on the currently available information about the geologic setting (i.e., the depth of the injection formations and the lack of evidence for the presence of transmissive faults or fractures), surface air and/or soil gas monitoring may not be required. However, we could re-visit this potential requirement as we continue with the permitting process (e.g., during further technical review, in response to public comments, or as noted below). .

Considerations based on the results of Pre-Operational Testing/Modeling Updates:

- *If, based on the results of planned pre-operational testing, uncertainties about the geologic setting are identified, the need for air and/or soil gas monitoring or other monitoring will be reconsidered.*

Quality Assurance Procedures

The review team evaluated the QASP to verify that all the testing activities, analytes, etc., included in the QASP are consistent with proposed injection and post-injection phase testing and monitoring. All the injection and post-injection testing and monitoring activities are addressed in the QASP and the QASP covers activities recommended by EPA. EPA noted some discrepancies between the tables in the QASP and the activities described in Attachments C and E. These are summarized in the table below:

QASP Table	**EPA comments**
Table 1. Summary of testing and monitoring.	*Please clarify that temperature and downhole pressure/ temperature monitoring in the injection well on Table 1 is for the purpose of injection operations monitoring, not reservoir monitoring, as shown (as this will not be performed in the injection wells).* *Please reference temperature logging and radioactive tracer logging for MIT on Table 1.*
Table 3. Summary of analytical and field parameters for ground water samples.	*Please revise the analytical methods in Table 3 to match the Testing and Monitoring Plan for: cations, dissolved CO_2, and pH (field).* *Please remove gravimetry for TDS measurement from Table 3 to be consistent with the Testing and Monitoring Plan.* *Please add analysis of dissolved methane via EPA-approved method SM 6211 B and/or 6211 Cto Table 3 to be consistent with the Testing and Monitoring Plan.*
Table 4. Summary of analytical parameters for CO_2 stream.	*Please add the parameters argon, hydrogen, oxides of nitrogen, ammonia, H_2O, and δ13C to this table to match the recommendations for the Testing and Monitoring Plan above.*
Table 17. Summary of sample containers, preservation treatments, and holding times for ground water samples.	*Please add H_2S, methane, cations of Zn, and anions of Ca to Table 17 to match Table 3 of the QASP (and recommendations for Attachments C and E above).* *Please also make other necessary revisions to Table 17 to address EPA's requests related to analytical parameters under "Ground Water Monitoring" above.*